Energy stability requirement of PEEM3 beamline and related angle resolution of monochromator

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April 9, 2003

One of the application of PEEM3 project is to measure the magnetic circular dichroism (MCD) of magnetic material. Since the MCD effect of some sample is very small, then the requirement of energy stability of the beamline during the measurement will be very high. For example, if we want to measure $1X10^{-4}$ MCD effect, what is the requirement of energy stability of the beamline and related angle resolution of monochromator?

Assuming the energy spectra of the beamline is of Gaussian distribution

$$I = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(E-E_0)^2}{2\sigma^2}} \qquad (1)$$

where I is intensity, and E_0 is the center energy. Now let us consider that another Gaussian distribution is shift by δE_0, then the intensity difference of this two Gaussian is

$$\frac{dI}{I_0} = e^{-\frac{(E-E_0)^2}{2\sigma^2}} \frac{(E-E0)}{\sigma^2} \delta E_0 \qquad (2)$$

If the beamline is center at 750ev, which is close to the magnetic material absorption edge, and the distribution is 1ev wide, then the intensity difference calculated according to eq.(2) is shown in figure 1. This intensity difference will be the noise of MCD measurement.

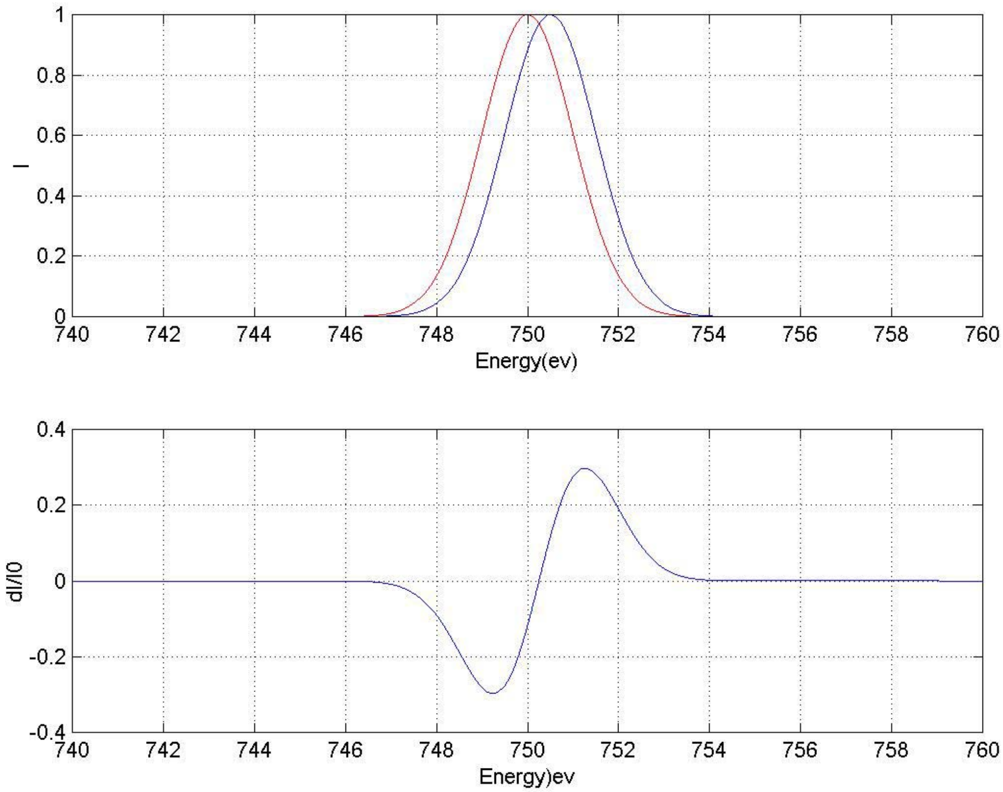

Figure 1. Background of MCD measurement generated by the shift of beamline energy spectra.

The amplitude of eq(2) can be got by making the differential of eq(2) equal to zero as following

$$\frac{dI}{I_0} = e^{-0.5} \frac{\delta E_0}{\sigma} \qquad (3)$$

Eq(3) shows that the intensity difference is linearly proportion to the energy spectra shift of beamline, the results according to eq(3) is shown in figure(2).

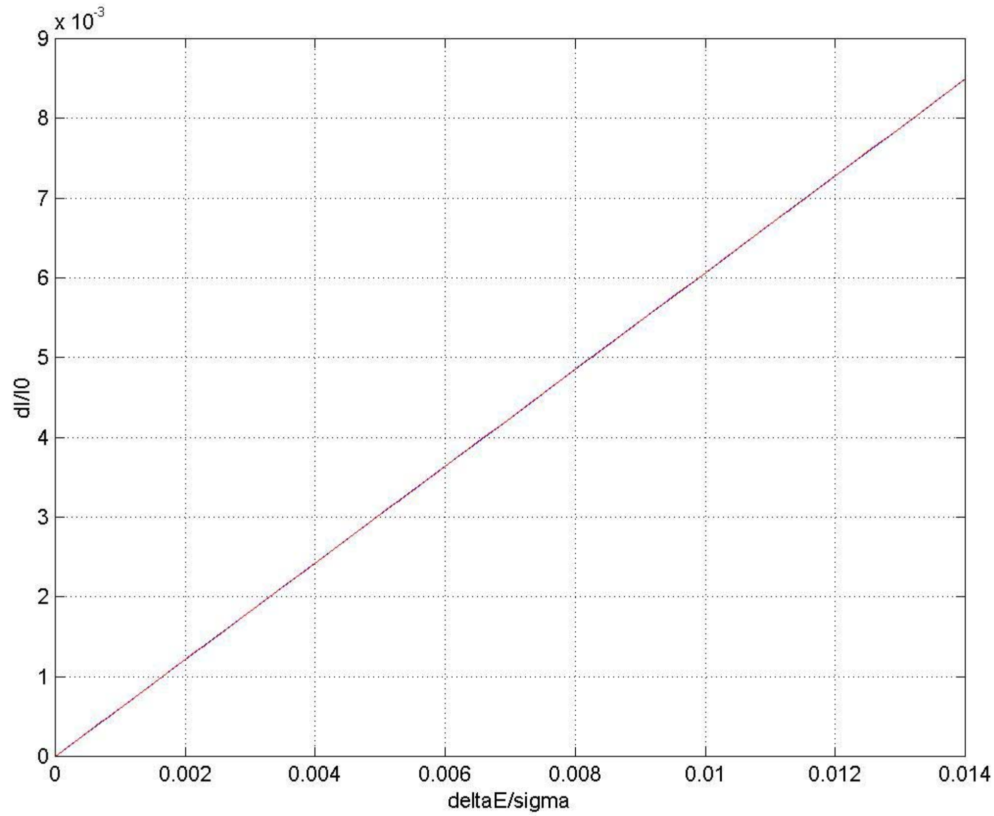

Figure.2 Background amplitude for MCD measurement with beamline shift amounts

Now we can answer the first part of our question: if we want to measure $1X10^{-4}$ MCD effect, what is the requirement of energy stability of the beamline? Since a line structure is typically 1ev wide, from eq(3), then the energy stability requirement is 0.165mev.

For PEEM3 beamline, a VLS monochromator will be used, the grating equation is

$$\lambda = 2d\cos\theta\sin\varphi \qquad (4)$$

where λ is wave length, d is grating groove spacing, θ is half of the including angle (which is 176 degree in our case), φ is the angle turned from zero order. By using the grating of density 500lines/mm, for 750ev energy, φ is 0.6785deg, so 0.0118rad.

we also know that

$$\frac{dE}{E} = \frac{d\varphi}{\varphi} \qquad (5)$$

then the angle resolution required for measuring $1X10^{-4}$ MCD effect will be

$$d\varphi = \frac{dE}{E}\varphi = \frac{0.165mev}{750ev}x0.0118 = 2.596x10^{-9}\,rad \qquad (6)$$

The beam will rotate by twice this angular error on reflection for zero order and propogate over the imaging distance of mono which is 7m , this means $2.596x10^{-9}x2x7m=36.34nm$.